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Teachers' Descriptions of Mathematics Graphics for Students with Visual Impairments: A Preliminary Investigation

L. Penny Rosenblum[1], Li Cheng[2], Kim Zebehazy[3], Robert Wall Emerson[4], and Carole R. Beal[2]

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Recent studies indicate that students with visual impairments (i.e., blindness or low vision) struggle when working with mathematics graphics such as line and bar graphs, circle graphs, and Venn diagrams (Beal & Rosenblum, 2018; Mazella et al., 2014; Morash & McKerracher, 2014). Students with visual impairments frequently report that they are not able to keep up with sighted classmates on mathematics problems that involve graphics (Zebehazy & Wilton, 2014b). Many teachers of students with visual impairments also report that their students are often not able to use mathematics graphics independently (Zebehazy & Wilton, 2014a).

Teachers of students with visual impairments clearly have an important opportunity to promote graphics literacy skills for students with visual impairments through providing descriptions to make educational content accessible. Guidelines for appropriate image descriptions have been developed by the National Center on Accessible Materials (NCAM), a leader in accessible multimedia design (The Carl and Ruth Shapiro Family National Center for Accessible Media, n.d.; Freed et al., 2015; Wall

[1] American Foundation for the Blind, Arlington, VA, USA
[2] University of Florida, Gainesville, FL, USA
[3] University of British Columbia, Vancouver, BC, Canada
[4] Western Michigan University, Kalamazoo, MI, USA

Corresponding author:
L. Penny Rosenblum, PhD, Public Policy and Research Institute, American Foundation for the Blind, Arlington, VA, USA.
Email: prosenblum@afb.org

Emerson & Anderson, 2018a, 2018b). Ideally, teachers of students with visual impairments would also help students to develop graph interpretation skills by asking them to explain, elaborate, or state relationships between elements, in addition to locating information in the graphic (Buchanan Hill, 2016; Panayiotou et al., 2014; Şahin, 2015; Zebehazy & Wilton, 2014a). However, to date, little is known about whether teachers' descriptions are consistent with established guidelines for accessibility, or how they help students locate and interpret graphical information.

In this preliminary study, we asked teachers of students with visual impairments (referred to as *teachers* for the remainder of the article) to describe graphics to two hypothetical students: a print reader with low vision and a braille reader. The use of hypothetical students was adopted to allow for a comparison of descriptions across teachers.

Method

Participants

A convenience sample of 10 teachers participated in the study. All were White females. Eight were itinerant teachers and two worked at schools for blind students. Their number of years teaching ranged from 4 to 25 ($M = 13.5$ years).

Materials

Twelve mathematics graphics used in prior research were selected, and descriptions were prepared by the fourth author based on NCAM guidelines (Rothberg & Gould, 2010) to provide a "gold standard" against which the teachers' descriptions could be compared. The NCAM descriptions were parsed to determine how many key elements were included. *Key elements* were defined as information that was critical to understanding the content and was different from other information in the description. For example, the following description includes six key elements: "There is a bar graph titled Lengths of Five White Sharks. Five blue bars labeled A, B, C, D, and E show the lengths of five white sharks in meters. A is 2.5, B is 3, C is 4, D is 5.5, and E is 6.5." The six elements are that there is a bar graph, the graph's title, the five blue bars, the labels of the bars, what the bars represent, and what each bar label corresponds to numerically. For the 12 graphics, the average number of elements was 11.3, with a range of 4–20.

Data collection and coding

Data were collected via a web-based survey platform. Teachers completed informed consent materials, provided demographic information and then viewed the 12 graphics on the screen in turn. For each graphic, the instructions were:

> In guiding a student to explore this graphic, what would you say to the student? Assume it is a student who needs guidance to interpret the graphic. Audio-record yourself explaining the graphic.

Teachers were asked to describe each graphic twice, once for a braille reader working at grade level and once for a print reader at grade level. For the braille reader, teachers were reminded to not provide any more information than what a print reader would be able to access. Teachers used smartphones to record themselves and submitted the audio files to the research team. The audio files were transcribed.

Graphics descriptions. The fourth author evaluated how many of the key elements of each NCAM description were included in the teachers' descriptions. An individual teacher

Table 1. Mean NCAM elements, suggestions, difficulty ratings, and questions per graphic by teacher.

Teacher	Mean percentage of NCAM elements per graphic	Mean number of suggestions per graphic	Mean difficulty rating per graphic	Mean number of questions per graphic
Kate	20.40	2.87	2.29	6.79
Gina	44.68	4.00	1.41	0
Amy	46.04	7.04	2.33	1.87
Jane	50.08	3.62	2.71	0
Carol	54.37	5.62	4.16	0.45
Beth	57.68	5.00	2.50	0.08
Helen	59.18	4.35	2.87	0.91
Ella	59.78	3.75	2.71	0
Dawn	64.92	5.29	1.65	0
Felicia	72.91	5.16	2.54	0.83

Note. Names included in the table are pseudonyms. NCAM = National Center on Accessible Materials.

received a score of 0, 0.25, 0.5, 0.75, or 1 for each key element, depending on how fully she included that key element in her description. These scores were then summed to give a score for how closely that teacher included the NCAM key elements in her description. Scores were converted to a percentage of key elements covered per description.

Graphics exploration suggestions. The first and second authors reviewed the transcripts for instances in which the teacher suggested a specific action that the student could take to locate or interpret information in a graphic (e.g., find state borders on a map, locate large wedge in a circle graph, use key to find the meaning of a symbol, look at labels below number line). The second author then tallied the number of different suggestions made by each teacher.

Use of questions. The third author identified all questions in the transcripts and then tallied them for each teacher.

Perceived difficulty of graphics. After the teachers made the audio recordings for each graphic, they were asked to rate their agreement with the statement "This would be a difficult image for a braille/print reader to understand," using a 5-point Likert-type scale (1 = *strongly disagree*, 2 = *disagree*, 3 = *not sure*, 4 = *agree*, 5 = *strongly agree*).

Familiarity with standards and guidelines. At the end of the session, the teachers were asked whether there were any guidelines they referenced when deciding how to describe graphics and whether they were familiar with the NCAM standards.

Results

Graphics descriptions

The average percentage of NCAM elements included in descriptions provided by teachers is shown in Table 1. Across all 12 descriptions, only about half of the key elements in the NCAM descriptions were included in the descriptions provided by the teachers. The number of key elements (or portions of key elements) varied significantly across teachers when considering all 12 descriptions: $F(9,220) = 12.86$, $p < .001$. When looking at each individual description, there was also a significant difference in the percentage of

key elements used by different teachers: $F(11,228) = 5.77$, $p < .001$. Note that these percentages reflect not only full use of key elements but also teacher descriptions that included partial aspects of key elements. There was no difference in the inclusion of key elements in the descriptions provided for print readers or braille readers.

Graphics exploration suggestions

On average, teachers included 4.97 suggestions per graphic for the hypothetical braille reader and 4.47 for the hypothetical print reader. However, as may be seen in Table 1, use of suggestions for locating information varied widely across teachers. One teacher included less than three suggestions per graphic on average, whereas another teacher generated almost eight suggestions per graphic.

Use of questions

As may be seen in Table 1, use of questions overall was low; four teachers did not include any questions. Most (82%) of the questions were posed by 2 of the 10 teachers and appeared to be used to confirm understanding or to verify that specific information could be located or discriminated. There were no instances of what might be considered higher order questions, for example, requesting the student to make a comparison or to give an explanation (Zebehazy & Wilton, 2014a). Only one teacher used questions to explicitly guide the student to find and interpret relevant information in the graphic, as illustrated in this example:

> When you get to the far, left side, what number do you see? That is your latitude measurement. Are you north or south of the equator? Are you far away from the equator or very close? Now put your right pointer finger on the Chicago dot again. This time, go straight up until you get to the top of the map. Do you see a number there? Keep your finger there, and use your other hand to look to the left and right of your finger. What numbers do you see? Is your finger closer to 90 or 85, or is it somewhere in the middle?

Difficulty ratings of graphics

Mean ratings may be seen in Table 1. Teachers reported that the graphics would be more difficult on average for a braille user ($M = 2.75$) than a print user ($M = 2.35$). In general, however, there was little consistency in teachers' ratings. Each of the 12 graphics was rated as very easy by at least one teacher, whereas others rated the same graphic as very difficult.

Familiarity with standards and guidelines

One teacher reported often referencing the NCAM standards for graphic descriptions; three participants had reviewed the standards; four had heard of the standards, but had not reviewed them; and two had never heard of the standards. One teacher who had heard of the standards, but who not reviewed them shared, "I would like more information about these standards[:] . . . one page with quick pointers on descriptions to help keep [me] on track for do's and don'ts."

Four participants mentioned the guidelines of the Braille Authority of North America (BANA, 2010) for preparing graphics. One stated, "I follow the BANA guidelines when considering how to adapt a graphic; that directly impacts how I describe a graphic."

Discussion

In this preliminary investigation, teachers described 12 mathematics graphics for a hypothetical print user and a hypothetical braille user. The major finding was that there was considerable variation among individual teachers in terms of how they described graphics for students, the number of specific

suggestions and questions for locating and interpreting information they provided, and which graphics they considered difficult. Teachers also varied in their awareness of the professional guidelines for the description of graphics as recommended by NCAM. On average, teachers only mentioned about half of the key elements that were included in the NCAM descriptions. About half of the teachers mentioned that they knew about the NCAM guidelines but were not familiar with their content, and two did not know the guidelines existed.

Overall, the findings point to the need for training to ensure that teachers are familiar with and are following existing guidelines for making graphics accessible. Training would also be valuable in helping teachers support students' graphics interpretation skills by posing questions that go beyond asking the student to locate information in the graphic (Zebehazy & Wilton, 2014a).

The study limitations include a small sample and the use of hypothetical students. One teacher noted, "It's extremely hard to describe without knowing the student and their abilities and struggles as well as being able to watch their reactions and adjust based on responses." Teachers might have incorporated more questions into their descriptions if they had interacted with real students. Also in the study protocol, teachers always first described the graphic for a braille reader before a print reader, which may have affected the descriptions. Finally, the actual effectiveness of the teachers' descriptions with students was not assessed.

Implications for practitioners

The findings point to the need to prepare practitioners to provide appropriate descriptions to make graphical materials accessible to students with visual impairments. Practitioners need to be provided with opportunities to become familiar with existing guidelines for description. Also, practitioners may wish to consider the use of questions to promote active engagement and critical thinking around graphics.

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